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ABSTRACT
Lathe machine is one of the primary machines used in industries' workshops and the production quality, time, cost, and safety of the turning process relies on the cutting tool type. Thus, smart manufacturers are seeking the appropriate tool for the desired workpiece's shape and material to optimize their manufacturing process. Applying the right tool for the right job and material is a powerful action needed for the lathe machines' operators to meet best market challenges. This paper discusses and reviewing several research found in optimizing the insert types used in a lathe machine for different materials. Therefore, recommending tables with the most valuable information about reviewing turning tools and their right use would be helpful for machine shops and industries to be followed in order to pick the right turning inserts for the right job.

Keywords – Turning operation, cutting tools, inserts, inserts coating.

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I. INTRODUCTION

Turning operation generally creates cylindrical symmetric shapes with a single-point contact tool. A single-point tool cuts off material from the workpiece by means of one cutting edge. In general, the turning process depends on holding the tool in almost a fixed position with the workpiece rotating about the turning axis. There are also some tools that can be held on the spindle centerline, like drills, reamers, and taps for hole-making or enlarging internal diameter purposes with specific speed and feed capability. In turning process, some important considerations must be taken into attention, such as the desired type of turning process, such as longitudinal or transverse turning, external or internal turning, and surface finish or tolerance, because these are the important factors that rely on the material that is being machined, equally well as the tools type applied [1]. As mentioned earlier, the tools used for turning are single-pointed contact and can be labeled into one full solid tools and a removable insert tools; these tools can be coated to improve the process and the tool's wear resistivity. Turning used to be carried out on a lathe machine, but the process has seen significant development, due to the expansion of computer numerical control (CNC) machines since the 1980s. This incident led to rise in their use in modern manufacturing industries developing from basic lathe machines, to multiple-process machining centers [2]. As the machines for turning grew, the tools that were being used in the process are developed from full one solid tools with simple geometries, usually made from steel, to coated cemented carbide tools, that make up to 80% of all tool inserts used in today's machining process. Thus, cutting tools today can be found in a variety of materials, which will conclude the right tool's properties for the right material and job. Coatings are placed on the tool's surface to provide extra wear resistance or a minor friction coefficient during the turning process, these coatings offer better way to machine materials at higher speeds, while maintaining overall decent surface quality, and extending the tool life, by reducing both tool cutting forces and contact temperature. Moreover, developments in cemented carbide tools took advanced level by fabricating these type of tools with gradient layers, where the surface layers are harder than the substrate ones [3]. Making these gradient composite tools will provide tools with more usefulness, as the required properties can be employed on the tools body and improved on the tools' surfaces and increasing their performance and the quality of the produced parts. Thus, the type and thickness of these gradients are very important and can reflect on the tool's performance. For example, the thickness of the gradient layer's found to have direct impact on cutting performance, which can be controlled by changing the contents of the cemented carbide components. Additionally, in the same study the authors concluded that the carbide with the thickest layer had the best cutting performance [4]. As stated by Sousa, V.F. and F.J. Silva in their study

[1], that Coatings can be achieved using two different methods, either by Chemical Vapor Deposition (CVD), or by Physical Vapor Deposition (PVD). Tool coatings are classified by their number of layers or layer arrangement and by their layer chemical composition. They are also characterized by their mechanical properties. Coatings can have different design levels, from single layer to multiple layered coating. These different design types of tool coating are as they follow and can be seen the following Fig. (1) [1, 5]:

a- Single layer coating
b- Double layer coating
c- Gradient coating
d- Multilayer coating
e- Nanolayered coating
f- Nanocomposite coating

The most design used in industries applications is the multilayer coating type, and by adding a greater number of layers, the contribution to hardness increases as well as crack propagation resistance increase. Therefore, this type of tool's coating is preferable due to its performance enhancement, making it very attractive to be used in the turning process.

The coating composition types applied to tools are borides, oxides, carbides, and nitrides. Some of the nitrides used as coatings on cutting instruments are CrAlN, TiN, TiAlSiN, TiAlN, , ZrN, TiSiN, and CrN [6]. carbides for coatings are WC, TiC, and CrC. For boride coatings, TiB_2 is used due to its chemical inertness, good wear resistance and high hardness as they can be attached to tool steel with specific adhesive qualifications [7]. As stated by Fernández-Abia et al. in their study [8], coatings are best suited for achieving low values of surface roughness (Ra), and they showed that by applying different coatings and their influences on the Ra of machining austenitic stainless steel 304L in the following Fig. (2). One can see in Fig. (2) using AlTiSiN is much better and stable in producing low roughness value for the machined part, while using TiAlCrN is the worest and with longer spiral cutting time application the roughness value increased by almost 80% than AlTiSin. Which means coatings have a huge impact on the inserts' performance and the machining quality. One of the most known and widely used oxide coatings is Al_2O_3 and the other somewhat common coatings for cutting tools are DLC, MoS_2 and WC-C. As mentioned earlier, mostly the turning process is done using a replaceable insert that is gripped on the edge of a turning tool body, which is usually mounted on the lathe machine tower, and a turning tool body with its replaceable insert can be seen in the next following Fig. (3).

Turning inserts are designed with highly engineered composite structures, geometry, and coatings features to attain enormous accuracy twin with high material removal rates. The most advantages of using replaceable inserts for turning tools are that inserts can be indexed to use the other edges when one becomes worn, and Inserts are quickly and easily to replace during the process. Thus, the use of the inserts must follow a clear world standard to be applied for the right tool body and job. The American National Standards Institute (ANSI) has established a coding system of numbers and letters to describe the dimensions, shape, and most crucial parameters of the turning inserts as can be seen in the following table 1.

1. <u>Shape:</u>

As demonstrated in the following Fig. (4), turning inserts are made in a variety of sizes, shapes, and cutting angles. The intended task and the efficiency of the cutting process depend on the shape. For instance, the square or even octagonal shape increases the number of isolated edges that can be utilized as one edge when the other wears out, while the round shape maximizes edge strength. The diamond shape can withstand a sharp point to cut precise and exact details.

Because C and W type turning inserts have a larger point contact angle and are therefore more stiff, they are typically utilized for rough machining. Finishing applications frequently use inserts like D and V, which have reduced point angles. However, their strength is lower than that of those with a wider point contact angle; a smaller angle is appropriate for more intricate parts. While vibration is one of the large point contact angle's drawbacks, it also offers some important benefits like stronger cutting edges, higher feed rates, and larger cutting forces. Conversely, the small point contact angle can be described as having a lower cutting force, a weaker cutting edge, and easier access to part details. , with lower vibration when compared to large point contact angle. A good figure found to summarize the correlation among the shape of the inserts and all cutting-edge strength, accessibility, vibration, and power consumption is shown in Fig. (5).

2. Clearance:

In order to avoid the insert's walls rubbing against the part and increasing the heat of friction, which could lead to poor machining quality and damage the insert, clearance is crucial when turning inserts. For rough machining, a turning insert with a 0° clearance angle is typically utilized. You can observe the various clearance angles in the accompanying figure (6).

3. Tolerances:

The turning inserts tolerances are very important to control cost and maintain functionality. Generally speaking, tighter tolerances mean higher cost will be applied to the process. The following table (2) shows the different turning inserts tolerances.

4. Type:

The turning insert has a different hole shape and chip breaker type as can be seen in the next Fig. (7). A chip breaker of the insert has a feature of disrupting the flow of chips and breaking them into short segments, rather than forming a long chewy chip. A clear figure of the chip breaker is shown in Fig. (8).

5. Size:

The rotating insert's cutting-edge length can be determined with the use of this numerical value. Furthermore, the depth of cut during the roughing process must never be greater than 50% of the insert's etched circle. The size for equal-sided inserts (0.25" I.C. or above) will be in increments of 1/8". Take (2 = 0.25, 4 = 0.5", etc.) as an example. The size will be expressed in 1/32" increments for equal-sided inserts (less than 0.25" I.C.); for example, (2 = 1/16", 4 = 1/8", etc.). Two numbers are needed for parallelograms and rectangles (Width and Length). Digit 1 represents width in 1/8" steps, while digit 2 represents length in 1/4" steps; for instance, 12 = 1/8" = 1/2".

6. Thickness:

The thickness of the inserts can be expressed as follows: 1/16" increments for inserts (1/4" I.C. or above), and 1/32" increments for inserts (less than 1/4" I.C.).

7. Corner or Nose:

It is always advantageous to choose a nose radius for turning operations that is lower than the depth of cut in order to minimize vibration throughout the process. Furthermore, a high nose radius is beneficial for raising radial pressures, deeper cuts, harder edges, and feed rates. However, the short nose radius reduces vibration, is utilized for small cutting depths, and undoubtedly has a poor cutting edge. Thus, while constructing the inserts to regulate the turning process quality, the nose radius, as seen in Fig. (9), is crucial.

Insert Materials and Their Use:

Insert is usually made of carbide, ceramic, cermet, or diamond materials and can be applied to different demanding applications. As mentioned earlier, a variety of protective coating types also help to improve these insert materials and make them stronger, cut faster, and last longer [11]. Therefore, in the following recommended table (3) most of the insert materials used in turning operations and their best use are shown. Moreover, another good study made by Li Qian & Mohammad R. Hossan [12], showed that there is a direct relation between tool nose radius and the machined material with a clear influence on the cutting force. The authors investigated four different tools using different tool nose radius, AISI 52100 bearing steel, AISI H13 hot work tool steel, AISI D2 cold work steel, and AISI 4340 low alloy steel, they stated that cutting forces change with a slight increasing trend for increasing tool edge radius. In their Fig. (10), it is showing that hard turning H13 gets the lowest changing trend and almost stable with all different nose radius, while hard turning 52100 gets the highest changing trend with an increasing in the cutting force by almost 45% between the smallest and the largest nose radius.

In general, the turning inserts geometry and material affecting different significant quality factors, such as surface roughness, tool wear, residual stresses, chip formation, heat generation and transfer, cutting force, hardness variation, vibration, and process time duration [1, 13]. We should put in mind that these quality factors are also related to the process main parameters and should not be neglected such as cutting speed, feed rate, and type of turning process, which all have great impact on tool wear or tool life, and equation (1) is concluding that and it is very important to calculate the tool life [14]. Therefore, it is very important to accurately pick the right inserts or coating type when these mentioned quality factors are desired, and some the important inserts’ material recommendations are shown in table (3).

II. INDENTATIONS AND EQUATIONS

Equation (1): Where (Vc) is the cutting speed, (T) is the tool life, (n & C) are constants determined by the work & tool materials, tool design, etc [14].

$$V_C . T^n = C$$

III. FIGURES AND TABLES

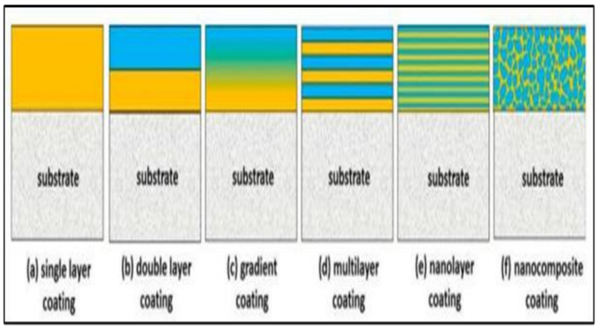


Fig. (1): Different designs of hard coating adapted from both studies [1, 5].

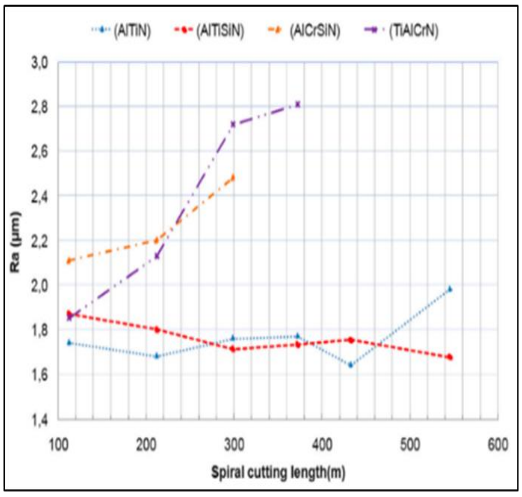


Fig. (2): A graph for different PVD coatings type and their production of surface roughness for machining 304L material, which was obtained by Fernández-Abia et al. [8].

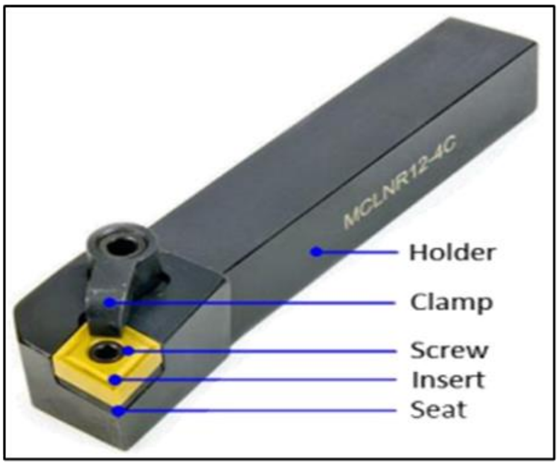


Fig. (3): A tool body with its replaceable insert [9].

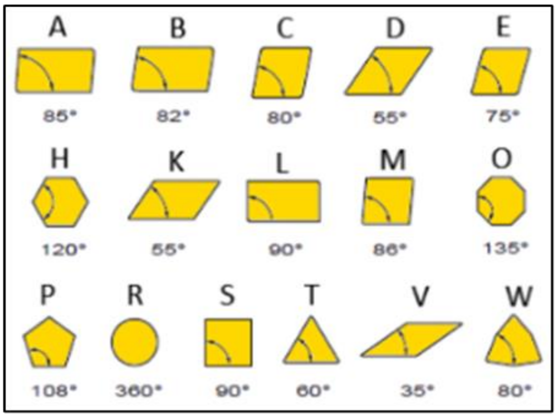


Fig. (4): The different shapes of turning inserts [9].

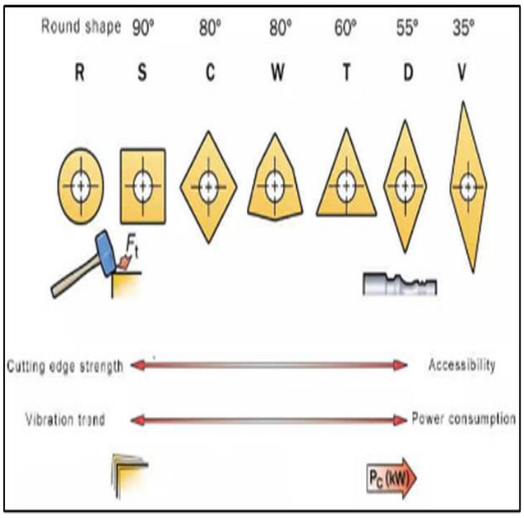


Fig. (5): The different inserts shapes and their influences on cutting-edge strength, accessibility, vibration, and power consumption [10].

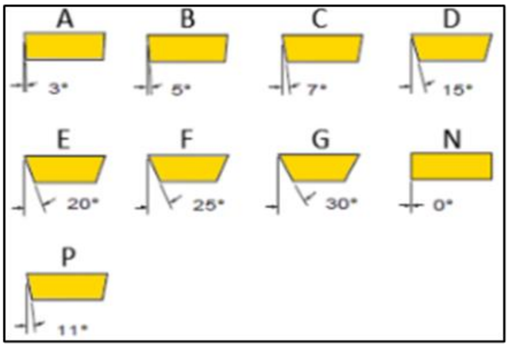


Fig. (6): The different clearance angle for turning inserts [9].

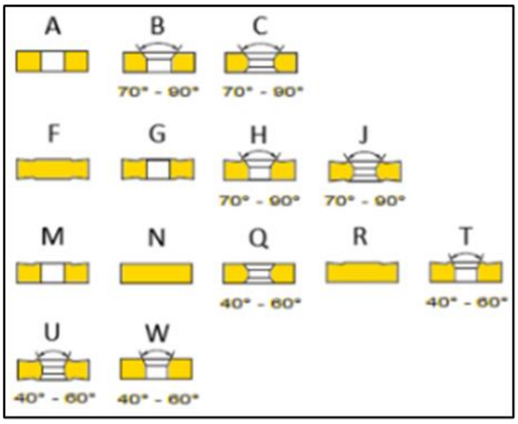


Fig. (7): The different hole shape and chip breaker in turning inserts [9].

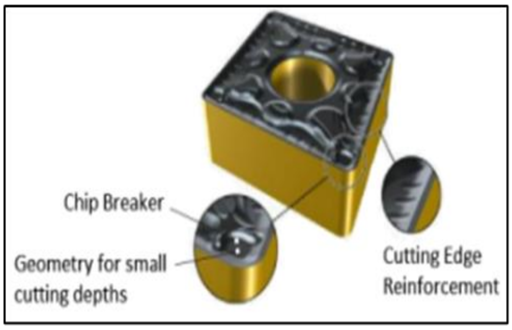


Fig. (8): The chip breaker, adopted from [9].

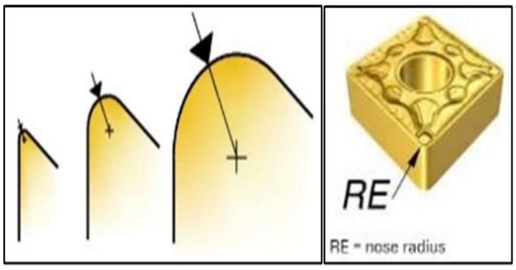


Fig. (9): The different nose radius on left, and the nose radius point showing on the right.

Table (1): The American National Standards Institute (ANSI) Coding System for Turning Inserts [9]

C	N	M	G	-	4	3	2
1	2	3	4		5	6	7
Shape	Clearance	Tolerance	Type		I.C. Size	Thickness	Nose Radius

Table (2): The turning inserts tolerances [9].

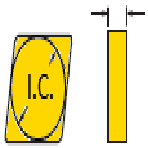
Letter	Inscribed Circle (I.C.)	Thickness	
A	±0.0002	±0.001	
B	±0.0002	±0.005	
C	±.0005	±0.001	
D	±0.0005	±0.005	
E	±0.001	±0.001	
F	±0.002 to ±0.004	±0.002	
G	±0.001	±0.005	
M	±0.002 to ±0.010	±0.005	
U	±0.005 to ±0.012	±0.005	

Table (3): The insert materials and their best applications [9]:

Insert Material	Applications
Polycrystalline diamonds (DP uncoated, HC coated)	In regions where abrasive agents would wear down other materials, the toughest material is used. It is not suitable for steel machining due to its significant chemical affinity for iron.
Cubic boron nitrides (BN)	the second-toughest substance. Its extraordinarily strong abrasion resistance is traded for a significant loss of hardness. The "hard machining" procedure, which involves running the tool or the item fast enough to melt it before it reaches the edge and greatly soften it, is the most popular use for it.
Ceramics (CA: Al2O3), (CM: Mixed ceramics), (CN: Si3N4), (CC: Si3N4 & coated)	Ceramics are generally selected in high-speed applications because of their exceptional heat resistance and chemical inertness, with their solitary drawback being their substantial fragility. Alumina (aluminum oxide), silicon carbide, and silicon nitride are the three ceramic materials that are most frequently utilized.
Cermets (HT: uncoated, HC: coated)	cement-based material that makes use of titanium carbide (TiC). Nickel is usually utilized as the binder. Compared to tungsten carbide, it is less robust but more resistant to abrasion. exceptional resistance to abrasion.
Cemented carbide (HW: uncoated, HC: coated)	the material that is currently most frequently utilized in the sector. It comes in several "grades" with different concentrations of tungsten carbide and binder, which is typically cobalt. strong resistance against abrasion.

IV. CONCLUSION

The importance of turning inserts to the machine shops and industries is that they can be used to produce components with high accuracy and reliability. They can also be used to produce components with complex geometry. In addition, they provide a cost-effective and efficient way to produce parts with repeatable accuracy and quality once they are picked wisely. Thus, the use of turning inserts can save time and money by reducing the number of setup processes and the number of tools that must be used in the production process. Turning inserts can be used to produce components with a variety of materials due to their heat-resistant properties. Therefore, using the right inserts or coatings type for the desired job in the turning process will improve the quality of the product and save money and time for the manufacturer, we have discussed the different types of turning inserts and coatings that are available in the market, and their advantages and disadvantages. We have also presented some of the factors that affect the performance and wear of the inserts, such as cutting speed, feed rate, depth of cut, tool geometry, and workpiece material. We have also reviewed some of the methods and techniques that are used to evaluate and optimize the selection of the inserts and coatings for different turning applications. We have highlighted some of the challenges and opportunities that exist in the field of turning inserts and coatings, such as developing new materials, improving the surface quality, reducing the environmental impact, and enhancing the productivity and efficiency of the turning process. We hope that this review will provide a useful reference for researchers and practitioners who are interested in the topic of turning inserts and coatings.

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